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BOX: PATENT APPLICATION

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Re: Application of Atsushi MAKINO
AUDIO DEVICE
Our Reference: Q59679

Dear Sir:

Attached hereto is the application identified above including the specification, claims, executed Declaration and Power of Attorney, fifteen (15) sheets of drawings, two (2) sheets of drawings legends, two (2) priority documents, executed Assignment and PTO Form 1595.

The Government filing fee is calculated as follows:

Total Claims	5 - 20 =	0 x \$18 =	\$ 000.00
Independent Claims	3 - 3 =	0 x \$78 =	\$ 000.00
Base Filing Fee	(\$690.00)		\$ 690.00
Multiple Dep. Claim Fee	(\$260.00)		\$ 000.00
TOTAL FILING FEE			\$ 690.00
Recordation of Assignment Fee			\$ 40.00
TOTAL U.S. GOVERNMENT FEE			\$ 730.00

Checks for the statutory filing fee of \$ 690.00 and Assignment recordation fee of \$ 40.00 are attached. You are also directed and authorized to charge or credit any difference or overpayment to Deposit Account No. 19-4880. The Commissioner is hereby authorized to charge any fees under 37 C.F.R. 1.16 and 1.17 and any petitions for extension of time under 37 C.F.R. 1.136 which may be required during the entire pendency of the application to Deposit Account No. 19-4880. A duplicate copy of this transmittal letter is attached.

Priority is claimed from:

Japanese Patent Application

P.Hei. 11-165651
P.2000-119787

Filing Date

June 11, 1999
April 20, 2000

Since the anniversary of the priority date fell on a Sunday, the filing of this application on Monday, June 12, 2000 is sufficient to obtain the benefit of priority.

Respectfully submitted,
SUGHRUE, MION, ZINN, MACPEAK & SEAS
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AUDIO DEVICE

BACKGROUND OF THE INVENTION

5 The present invention relates to an audio device which corrects a delocalization of a center sound image or an asymmetrical expansion of a sound field in a reproduction sound field, such as a car cabin or a listening room, to thereby provide a natural sound space to listeners.

10 In a conventional audio device, right- and left-channel speakers 5 and 6 are disposed in a reproduction sound field space 4, such as a listening room, as typically shown in Fig. 17A. When a listener hears a stereophonic sound or the like at the center in front of the speakers 5 and 6, a center sound image C, such as vocal, is localized in front of the listener.

15 When the listener listens at a position asymmetrically located with respect to the speakers 5 and 6, the center sound image C is delocalized, thereby failing to produce a natural sound field space.

20 A car-carried audio device is known as a typical case where the center sound image C is likely to be delocalized. The car-carried audio device is used in a special place, viz., within a car cabin of an automobile. Accordingly, it is common practice that the left- and right-channel speakers 1 and 2, as typically shown in Fig. 17B, are disposed at a position

25 located asymmetrical with respect to a passenger (listener).

Therefore, the center sound image C, such as vocal, to be localized in front of the listener is delocalized to a position closer to the speaker 2 disposed closer to the listener.

To cope with the delocalization problem of the center
5 sound image within the car cabin, there is proposed car-carried
audio devices with a balance adjustment function and a time
alignment function.

In the car-carried audio device with the balance
adjustment function, as shown in Fig. 17C, an output level of
10 the speaker 2 located closer to the listener is reduced to be
lower than the output level of the speaker 1 located farther
from the listener by an amplitude adjustment circuit 7. As
a result, the sound pressure levels of the right- and
left-channels are balanced with respect to the listener to
15 localize the center sound image C in front of the listener.

In the car-carried audio device with the time alignment
function, as shown in Fig. 17D, an audio signal is supplied
to the speaker 1 located farther from the listener, and after
some time elapses, an audio signal is supplied to the speaker
20 2 closer to the listener, whereby the right- and left-channel
sounds reach the listener at the same time, and the center sound
image C is localized in front of the listener.

A head related transfer function (HRTF) correction
method is known. In the HRTF basis correction method, a sound
25 field of a concert hall or the like is simulated or a sound

image is localized in a desired direction by controlling a transfer function (amplitude and phase characteristics) of a space between a speaker and the ears of a listener. Attempt has been made to correct a delocalization of a sound image or
5 to enlarge a sound field by applying the HRTF correction method to the car-carried audio device.

The audio devices with the balance adjusting function and the time alignment function are capable of localizing the center sound image in front of the listener, indeed. However,
10 it is difficult to remove the asymmetric expansion of a sound field as viewed in the horizontal direction.

In the case of using the head related transfer functions, a great amount of audio signals must be digital processed for an extremely short time. Therefore, the signal processing
15 circuit of a large scale and high speed is required.

FIR (Finite Impulse Response) digital filters, for example, are used for the signal processing circuits to realize the head related transfer functions. In this case, a great number of filter coefficients and delay elements are required
20 so as to satisfactorily correct complicated sound field characteristics. Increase of the circuit scale and processing speed is unavoidably imparted on the signal processing circuit.

Even if the deformation of the sound field is corrected by the HRTF basis correction method which uses the signal
25 processing circuit of large scale and high speeds, the

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correction is effective only under limited conditions. If the listener is constantly static, the transfer functions in a space ranging from the right and left speakers to the right and left ears of the listener including his head remain unchanged. Therefore, the correction improvement is achieved under that condition. Actually, in the car-carried audio device, the listener frequently moves his head in the driving operation, and in the audio device installed in a living room, the listener is not always static. Accordingly, the transfer functions in a space from the right and left speakers to the listener vary, and it is impossible to quickly change the head related transfer functions following the distance change.

SUMMARY OF THE INVENTION

15 The present invention has been made to solve the above problems, and an object of the invention is to provide an audio device which provides a natural sound field to a listener by correcting a delocalization of a center sound image and an expanding asymmetrically as viewed in the horizontal direction
20 in a reproduction sound field.

To achieve the above object, there is provided an audio device having a correction circuit having given transfer functions, which audio device supplies, through the correction circuit, right- and left-channel input audio signals on which head related transfer functions are superimposed, to right-

and left-channel speakers located in front of a hearing position of a listener in a reproduction sound field space. The audio device is improved in that correction transfer functions obtained by an inverse matrix of a matrix of which

5 the elements are the following first to fourth transfer functions are implanted in the correction circuit; a first transfer function featured by a sound field characteristic of a space ranging from a left-channel speaker to the left ear of the listener when the left-channel speaker is disposed in

10 an anechoic room as a model of a component layout in the reproduction sound field space, a second transfer function featured by a sound field characteristic of a space ranging from a left-channel speaker to the right ear of the listener when the left-channel speaker is disposed in an anechoic room

15 as a model of a component layout in the reproduction sound field space, a third transfer function featured by a sound field characteristic of a space ranging from a right-channel speaker to the left ear of the listener when the right-channel speaker is disposed in an anechoic room as a model of a component layout

20 in the reproduction sound field space, and a fourth transfer function featured by a sound field characteristic of a space ranging from a right-channel speaker to the right ear of the listener when the right-channel speaker is disposed in an anechoic room as a model of a component layout in the

25 reproduction sound field space.

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The correction transfer functions of the correction circuit have the called inverse characteristics of transfer functions featured by sound field characteristics in a space ranging from the speakers of both channels. When audio signals are input to the correction circuit, the correction circuit corrects the input audio signals so as to suppress the influence by the sound field characteristics, and supplies the corrected ones to the speakers of both channels. Therefore, the influence of a delocalization of a center sound image of sounds generated by the speakers, an expanding asymmetrically as viewed in the horizontal direction in a reproduction sound field, and the like are cancelled by the reproduction sound field characteristics. Therefore, the listener hears sounds equivalent to the sounds reproduced from the input audio signals on which head related transfer functions defined when he hears sounds in a sound field.

According to another aspect of the invention, there is provided an audio device comprising a correction circuit having given transfer functions, which audio device supplies, through the correction circuit, right- and left-channel input audio signals on which head related transfer functions are superimposed, to right- and left-channel speakers located in front of a hearing position of a listener in a reproduction sound field space. In the audio device, correction transfer functions, which are obtained in accordance with a plurality

of spatial regions within a predetermined reproduction sound field space by an inverse matrix of a matrix of which the elements are the following first to fourth transfer functions are implanted in the correction circuit are determined in advance; the first transfer function featured by a sound field characteristic of a space ranging from a left-channel speaker to the left ear of the listener when the left-channel speaker is disposed in an anechoic room as a model of a component layout in the reproduction sound field space, the second transfer function featured by a sound field characteristic of a space ranging from a left-channel speaker to the right ear of the listener when the left-channel speaker is disposed in an anechoic room as a model of a component layout in the reproduction sound field space, the third transfer function featured by a sound field characteristic of a space ranging from a right-channel speaker to the left ear of the listener when the right-channel speaker is disposed in an anechoic room as a model of a component layout in the reproduction sound field space, and the fourth transfer function featured by a sound field characteristic of a space ranging from a right-channel speaker to the right ear of the listener when the right-channel speaker is disposed in an anechoic room as a model of a component layout in the reproduction sound field space. Further, the audio device comprises: storing means for storing correction transfer functions corresponding to a plurality of spatial

regions; and position detecting means for specifying a hearing position of the listener in the plurality of spatial regions, wherein of the correction transfer functions stored in the storing means, the correction transfer functions specified according to a hearing position of the listener detected by the position detecting means are implanted in the correction circuit.

When a hearing position of the listener is changed, the position detecting means applies the correction transfer functions based on the changed hearing position. Therefore, the listener hears a stereophonic reproduction sound while being unconscious of the hearing position.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing an arrangement of an audio device 9 which is a first embodiment of the present invention.

Fig. 2 is an explanatory diagram for explaining a method of setting the transfer functions of the operator circuits.

Fig. 3 is an explanatory diagram for further explaining the method of setting the transfer functions of the operator circuits.

Figs. 4A to 4D are graph exemplarily showing waveforms of impulse response series measured in an anechoic room, with the ordinate representing an amplitude of the impulse response

and the abscissa representing time.

Figs. 5A to 5D are graph showing the frequency characteristics of the impulse response series shown in Fig. 4, with the ordinate representing power and the abscissa representing frequency.

Figs. 6A to 6D are graph exemplarily showing waveforms of impulse response series of the operator circuits in the first embodiment, with the ordinate representing an amplitude of the impulse response and the abscissa representing time.

Figs. 7A to 7D are graph showing the frequency characteristics of the impulse response series shown in Fig. 6, with the ordinate representing power and the abscissa representing frequency.

Figs. 8A to 8D are graph exemplarily showing waveforms of impulse response measured in a car cabin, with the ordinate representing an amplitude of the impulse response and the abscissa representing time.

Figs. 9A and 9B are graph showing waveforms of one impulse response series of Fig. 8 and one impulse response series of Fig. 4.

Figs. 10A and 10B are graph for explaining a setting method of setting operator circuits in a second embodiment of the present invention.

Fig. 11 is a block diagram showing an arrangement of an audio device which is a third embodiment of the present

invention.

Fig. 12 is a block diagram showing an arrangement of the audio device body in Fig. 11.

Fig. 13 is a plan view showing an external appearance
5 of a remote controller.

Fig. 14 is an explanatory diagram for explaining the function of the remote controller.

Fig. 15 is a diagram typically showing data stored in
a storage unit.

Fig. 16 is a block diagram showing an arrangement of a
10 modification of the third embodiment of the present invention.

Figs. 17A to 17D are explanatory diagram for explaining problems of the conventional technique.

15 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments of an audio device according to the invention will be described in detail with reference to the accompanying drawings.

(1st Embodiment)

20 Fig. 1 is a block diagram showing an arrangement of an audio device 9 which is a first embodiment of the present invention. While the invention is not limited to a home use audio device, a car-carried audio device or the like, the invention will be described in the form of a car-carried audio
25 device 9, for ease of explanation.

In Fig. 1, the audio device 9 is made up of a head related transfer function (HRTF) circuit 10a, a correction circuit 10b, output amplifiers 11 and 12, and a couple of speakers 13 and 14 attached to the inside of a car cabin 15. The speakers 13 and 14 are located at the right and left positions with respect to a passenger (listener) 16, for example, the right and left side positions on a front dashboard in the car cabin 15 or the front doors.

The HRTF circuit 10a includes operator circuits a1 to a4 and adder circuits a5 and a6. The HRTF circuit 10a superimposes amplitude/phase characteristics or head related transfer functions, which are equivalent to those defined when a listener hears a sound in a sound field, onto input audio signals Lin and Rin, by use of the operator circuits a1 to a4 and the adder circuits a5 and a6.

More specifically, audio signals Lin and Rin of right and left channels, which are generated by a reproduction or playback device as a sound source coupled to the audio device 9, such as a CD (compact disc) or MD (mini disc) reproduction or playback device for reproducing or playing back a sound from a recording medium, such as a CD or an MD, in which an audio source is recorded in a sound field in a concert hall, a recording studio or the like, are input to the operator circuits a1 to a4 of the HRTF circuit, as shown. The output signals of those operator circuits a1 to a4, which have respectively

transfer functions H_{t11} , H_{t12} , H_{t21} , and H_{t22} , are added by the adder circuits a_5 and a_6 , whereby the audio device 9 generates right-and left-channel audio signals SL and SR on which the head related transfer functions defined when the
5 listener hears a sound in a sound field are superimposed.

The transfer functions, which are implanted in the operator circuits a_1 to a_4 , are not the transfer functions in a space ranging from a sound source to sound recording microphones when only the microphones are located in a sound
10 field, but the transfer functions H_{t11} , H_{t12} , H_{t21} , and H_{t22} in a sound field, which are equivalent to those where a listener actually hears a sound by his right and left ears inclusive of his head.

More specifically, the transfer functions H_{111} , H_{t12} ,
15 H_{t21} , and H_{t22} are obtained by the inverse matrix of a regular matrix containing the following elements: a sound field characteristic of a space between a sound source located on the left side of a listener and the left ear of the listener; a sound field characteristic of a space between the sound source
20 on the left side of the listener and the right ear; a sound field characteristic in a space between a sound source located on the right side of the listener to the left ear; and a sound field characteristic in a space from a sound source located on the right side of the listener to the right ear. In this
25 way, the above-mentioned head related transfer functions

inclusive of the listener's head are realized.

The correction circuit 10b carries out a correction process to be given later for correcting the audio signals SL and SR on which the head related transfer functions defined when the listener hears sounds in a sound field. Right- and left-channel audio signals L and R, which are generated (output) as the result of the correction process are supplied to the right and left speakers 13 and 14, through the output amplifiers 11 and 12.

The audio signals SL and SR that are input to the correction circuit 10b are digital audio signals, which are digitized at a given sampling frequency although not illustrated. Those digital audio signals are subjected to the correction process mentioned above. The digital audio signals thus corrected are converted into analog audio signals by a D/A converter (not shown), and input to the output amplifiers 11 and 12.

Next, the correction circuit 10b will be described in detail. The correction circuit 10b contains operator circuits 17 to 20 each formed with an infinite impulse response (IIR) digital filter for carrying out the correction process.

The operator circuits 17 and 18 receives the audio signal SL, and the operator circuits 19 and 20 receive the audio signal SR. The output signals of the operator circuits 17 and 19 are added together by an adder circuit 21, to thereby generate a

left-channel audio signal L. The output signals of the operator circuits 18 and 20 are added together by an adder circuit 22 to generate a right-channel audio signal R.

Transfer functions H11, H12, H21 and H22 (referred to as correction transfer functions) are implanted in the operator circuits 17 to 20. Meanwhile, when sounds are emitted from the speakers 13 and 14 and reach the right and left ears 16L and 16R of the listener 16, the sounds are adversely affected by the sound field characteristic within the car cabin 15. The transfer functions are designed so as to suppress such adverse influences. A design process of those operator circuits will be described.

A model of a layout of the speakers, and the listener in the car cabin 15 is formed. A dummy listener 16 and the right and left speakers 13 and 14 are disposed within an anechoic room 23 in accordance with the cabin model.

In this state, only the speaker 13 is driven to generate a pulse sound. A sound which reaches the left ear 16L of the listener and a sound which reaches the left ear 16R of the listener are gathered by microphones, respectively. An impulse response series $a_{LL}(t)$ in a space between the speaker 13 and the left ear 16L as shown in Fig. 4A and an impulse response series $a_{LR}(t)$ in a space between the speaker 13 and the right ear 16R as shown in Fig. 4B are measured.

Then, the impulse response series $a_{LL}(t)$ is Fourier

transformed into a frequency characteristic PaLL (referred to as a transfer function ALL) as shown in Fig. 5A. The impulse response series aLR(t) is also Fourier transformed into a frequency characteristic PaLR (referred to as a transfer function ALR) as shown in Fig. 5B.

A sound pulse is emitted from only the right speaker 14, and a sound reaching the right ear 16R and a sound reaching the right ear 16R are gathered by the microphone. An impulse response series aRL (t) in a space between the speaker 14 and the left ear 16L as shown in Fig. 4C and an impulse response series aRR(t) in a space between the speaker 14 and the right ear 16R as shown in Fig. 4D are measured.

Then, the impulse response series aRL (t) is Fourier transformed into a frequency characteristic PaRL (referred to as a transfer function ARL), and the impulse response series aRR(t) is Fourier transformed into a frequency characteristic PaRL (referred to as a transfer function ARR).

An inverse matrix A-1 of a 2-row and 2-column regular matrix A of which the elements are the transfer functions ALL, ALR, ARL and ARR is obtained. The elements of the inverse matrix are used as correction transfer functions H11, H12, H21 and H22 of the operator circuits 17 to 20. The correction transfer functions H11, H12, H21 and H22 are given by the following equations (1) to (5).

1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057 2058 2059 2060 2061 2062 2063 2064 2065 2066 2067 2068 2069 2070 2071 2072 2073 2074 2075 2076 2077 2078 2079 2080 2081 2082 2083 2084 2085 2086 2087 2088 2089 2090 2091 2092 2093 2094 2095 2096 2097 2098 2099 2100 2101 2102 2103 2104 2105 2106 2107 2108 2109 2110 2111 2112 2113 2114 2115 2116 2117 2118 2119 2120 2121 2122 2123 2124 2125 2126 2127 2128 2129 2130 2131 2132 2133 2134 2135 2136 2137 2138 2139 2140 2141 2142 2143 2144 2145 2146 2147 2148 2149 2150 2151 2152 2153 2154 2155 2156 2157 2158 2159 2160 2161 2162 2163 2164 2165 2166 2167 2168 2169 2170 2171 2172 2173 2174 2175 2176 2177 2178 2179 2180 2181 2182 2183 2184 2185 2186 2187 2188 2189 2190 2191 2192 2193 2194 2195 2196 2197 2198 2199 2200 2201 2202 2203 2204 2205 2206 2207 2208 2209 2210 2211 2212 2213 2214 2215 2216 2217 2218 2219 2220 2221 2222 2223 2224 2225 2226 2227 2228 2229 2230 2231 2232 2233 2234 2235 2236 2237 2238 2239 2240 2241 2242 2243 2244 2245 2246 2247 2248 2249 2250 2251 2252 2253 2254 2255 2256 2257 2258 2259 2260 2261 2262 2263 2264 2265 2266 2267 2268 2269 2270 2271 2272 2273 2274 2275 2276 2277 2278 2279 2280 2281 2282 2283 2284 2285 2286 2287 2288 2289 2290 2291 2292 2293 2294 2295 2296 2297 2298 2299 2300 2301 2302 2303 2304 2305 2306 2307 2308 2309 2310 2311 2312 2313 2314 2315 2316 2317 2318 2319 2320 2321 2322 2323 2324 2325 2326 2327 2328 2329 2330 2331 2332 2333 2334 2335 2336 2337 2338 2339 2340 2341 2342 2343 2344 2345 2346 2347 2348 2349 2350 2351 2352 2353 2354 2355 2356 2357 2358 2359 2360 2361 2362 2363 2364 2365 2366 2367 2368 2369 2370 2371 2372 2373 2374 2375 2376 2377 2378 2379 2380 2381 2382 2383 2384 2385 2386 2387 2388 2389 2390 2391 2392 2393 2394 2395 2396 2397 2398 2399 2400 2401 2402 2403 2404 2405 2406 2407 2408 2409 2410 2411 2412 2413 2414 2415 2416 2417 2418 2419 2420 2421 2422 2423 2424 2425 2426 2427 2428 2429 2430 2431 2432 2433 2434 2435 2436 2437 2438 2439 2440 2441 2442 2443 2444 2445 2446 2447 2448 2449 2450 2451 2452 2453 2454 2455 2456 2457 2458 2459 2460 2461 2462 2463 2464 2465 2466 2467 2468 2469 2470 2471 2472 2473 2474 2475 2476 2477 2478 2479 2480 2481 2482 2483 2484 2485 2486 2487 2488 2489 2490 2491 2492 2493 2494 2495 2496 2497 2498 2499 2500 2501 2502 2503 2504 2505 2506 2507 2508 2509 2510 2511 2512 2513 2514 2515 2516 2517 2518 2519 2520 2521 2522 2523 2524 2525 2526 2527 2528 2529 2530 2531 2532 2533 2534 2535 2536 2537 2538 2539 2540 2541 2542 2543 2544 2545 2546 2547 2548 2549 2550 2551 2552 2553 2554 2555 2556 2557 2558 2559 2560 2561 2562 2563 2564 2565 2566 2567 2568 2569 2570 2571 2572 2573 2574 2575 2576 2577 2578 2579 2580 2581 2582 2583 2584 2585 2586 2587 2588 2589 2590 2591 2592 2593 2594 2595 2596 2597 2598 2599 2600 2601 2602 2603 2604 2605 2606 2607 2608 2609 2610 2611 2612 2613 2614 2615 2616 2617 2618 2619 2620 2621 2622 2623 2624 2625 2626 2627 2628 2629 2630 2631 2632 2633 2634 2635 2636 2637 2638 2639 2640 2641 2642 2643 2644 2645 2646 2647 2648 2649 2650 2651 2652 2653 2654 2655 2656 2657 2658 2659 2660 2661 2662 2663 2664 2665 2666 2667 2668 2669 2670 2671 2672 2673 2674 2675 2676 2677 2678 2679 2680 2681 2682 2683 2684 2685 2686 2687 2688 2689 2690 2691 2692 2693 2694 2695 2696 2697 2698 2699 2700 2701 2702 2703 2704 2705 2706 2707 2708 2709 2710 2711 2712 2713 2714 2715 2716 2717 2718 2719 2720 2721 2722 2723 2724 2725 2726 2727 2728 2729 2730 2731 2732 2733 2734 2735 2736 2737 2738 2739 2740 2741 2742 2743 2744 2745 2746 2747 2748 2749 2750 2751 2752 2753 2754 2755 2756 2757 2758 2759 2760 2761 2762 2763 2764 2765 2766 2767 2768 2769 2770 2771 2772 2773 2774 2775 2776 2777 2778 2779 2780 2781 2782 2783 2784 2785 2786 2787 2788 2789 2790 2791 2792 2793 2794 2795 2796 2797 2798 2799 2800 2801 2802 2803 2804 2805 2806 2807 2808 2809 2810 2811 2812 2813 2814 2

$$H_{11} = \frac{A_{RR}}{A_{LL}A_{RR} - A_{RL}A_{LR}} \quad \text{-----} \quad (2)$$

$$H_{21} = \frac{-A_{RL}}{A_{LL}A_{RR} - A_{RL}A_{LR}} \quad \text{----- (4)}$$

16

The correction transfer functions H11, H12, H21 and H22 are realized by use of IIR (infinite impulse response) digital filters, and those filters are incorporated into the operator circuits 17 to 20, respectively.

5 Impulse responses of the operator circuits 17 to 20 having the correction transfer functions H11, H12, H21 and H22 thus calculated are as shown in Figs. 6A to 6D. Those impulse responses are Fourier transformed into transfer functions (frequency characteristics) over the frequency regions as
10 shown in Figs. 7A to 7D.

 The correction circuit 10b is constructed as described above. The head related transfer functions defined when the listener hears sounds in a sound field are superimposed on the right- and left-channel audio signals emitted from a sound
15 source device, to thereby form the stereophonic audio signals SL and SR. Those stereophonic audio signals are actually input to the speakers 13 and 14 in a car cabin 15, through the correction circuit 10b. Then, the following effects will be produced.

20 Assuming that a transfer function of a space from the speaker 13 to the left ear 16L of the listener 16 within an actual car cabin 15 in Fig. 1, is BLL, a transfer function from the speaker 13 to the right ear 16R is BLR, a transfer function from the speaker 14 to the right ear 16R is BLL, and a transfer
25 function from the speaker 14 to the right ear 16R is BRR, and

[illegible]

5

18

Here, the correction transfer functions H_{11} , H_{12} , H_{21} and H_{22} are defined by the inverse matrix of the regular matrix A of which the elements are the transfer functions A_{LL} , A_{LR} , A_{RL} , A_{RR} in the sound field shown in Fig. 2. When the audio signals
5 SL and SR are applied to the correction circuit 10b, the sound field characteristic of the car cabin 15 is cancelled (corrected) by those correction transfer functions H_{11} , H_{12} , H_{21} and H_{22} . Therefore, the listener 16 hears sounds equivalent to those reproduced from the audio signals SL and
10 SR on which the head related transfer functions defined when the listener hears in a sound field. Accordingly, the center sound image is localized in front of the listener 16, and the listener hears the sounds in a sound field expanding symmetrically with respect to the listener in the horizontal
15 direction.

The correction transfer functions H_{11} , H_{12} , H_{21} and H_{22} are constructed on the basis of the impulse response series $a_{LL}(t)$ to $a_{RR}(t)$ of relatively simple waveforms as shown in Figs. 4A to 4D, which are measured in the anechoic room 23 as
20 a model of the car cabin 15. The correction circuit 10b may be constructed by use of simple IIR digital filters, while in the conventional technique, the transfer functions for correcting the sound characteristic of the whole car cabin 15 is constructed by use of the head related transfer function
25 correction method.

(Second Embodiment)

A second embodiment of the present invention will be described with reference to the accompanying drawings. A car-carried audio device will be described as a preferred
5 embodiment of the invention.

An audio device of the second embodiment resembles in construction the audio device 9 shown in Fig. 1.

In the second embodiment, the correction transfer functions H11, H12, H21 and H22 of the operator circuits 17
10 to 20 are constructed on an algorithm different of the first embodiment. The following method is used for constructing those operator circuits.

As in the case shown in Fig. 2, a model of a layout of the speakers, and the listener in the car cabin 15 is formed. A dummy listener 16 and the right and left speakers 13 and 14 are disposed within an anechoic room 23 in accordance with the cabin model. In this state, only the left speaker 13 located in the anechoic room 23 is driven to emit a pulse sound. In this state, only the speaker 13 disposed in the anechoic room
20 23 is driven to generate a pulse sound. A sound which reaches the left ear 16L of the dummy listener 16 and a sound which reaches the left ear 16R are gathered by microphones, respectively. Impulse response series $a_{LL}(t)$ and $a_{LR}(t)$ as shown in Figs. 4A and 4B are measured.

25 Further, only the right speaker 14 located in the

anechoic room 23 is driven to emit a pulse sound. In this state, only the speaker 13 disposed in the anechoic room 23 is driven to generate a pulse sound. A sound which reaches the left ear 16L of the dummy listener 16 and a sound which reaches the left ear 16R are gathered by microphones, respectively. Impulse response series $a_{LL}(t)$ and $a_{LR}(t)$ as shown in Figs. 4C and 4D are measured.

Only the left speaker 13 located in an actual car cabin 15 is driven to emit a pulse sound as shown in Fig. 3. A sound which reaches the left ear 16L of a listener 16 and a sound which reaches the left ear 16R are gathered by microphones, respectively. Impulse response series $y_{LL}(t)$ and $y_{LR}(t)$ are measured.

Only the right speaker 14 located in an actual car cabin 15 is driven to emit a pulse sound. A sound which reaches the left ear 16L of the listener 16 and a sound which reaches the left ear 16R are gathered by microphones, respectively. Impulse response series $y_{RL}(t)$ and $y_{RR}(t)$ are measured.

Figs. 8A to 8D show waveforms of impulse response series $y_{LL}(t)$, $y_{LR}(t)$, $y_{RL}(t)$ and $y_{RR}(t)$ thus measured.

The impulse response series $y_{LL}(t)$ and $a_{LL}(t)$ are compared as shown in Figs. 9A and 9B. Further, as shown in Figs. 10A and 10B, the impulse response series $y_{LL}(t)$ is amplitude modulated by an envelope CV within a period ΔT of time taken for the impulse response series $a_{LL}(t)$ to decrease

in amplitude to approximately 0 (zero) (viz., a period during which a damping amplitude decreases to approximately 0). In other words, a part of the impulse response series $y_{LL}(t)$ which corresponds to the impulse response series $a_{LL}(t)$ is extracted, and amplitude modulated by the envelope CV to form an impulse response series $y'_{LL}(t)$ as shown in Fig. 10A.

Other impulse response series $y_{LR}(t)$, $y_{RL}(t)$, and $y_{RR}(t)$ are also amplitude modulated in like manner by use of the impulse response series $a_{LR}(t)$, $a_{RL}(t)$ and $a_{RR}(t)$ to form amplitude-modulated impulse response series $y'_{LR}(t)$, $y'_{RL}(t)$, and $y'_{RR}(t)$.

Specifically, the impulse response series $y_{LR}(t)$ is amplitude modulated by an envelope of the impulse response series $a_{LR}(t)$ within a period of time taken for the impulse response series $a_{LR}(t)$ to decrease in amplitude to 0, to thereby form an impulse response series $y'_{LR}(t)$. The impulse response series $y_{RL}(t)$ is amplitude modulated by an envelope of the impulse response series $a_{RL}(t)$ within a period of time taken for the impulse response series $a_{RL}(t)$ to decrease in amplitude to 0, to thereby form an impulse response series $y'_{RL}(t)$. The impulse response series $y_{RR}(t)$ is amplitude modulated by an envelope of the impulse response series $a_{RR}(t)$ within a period of time taken for the impulse response series $a_{RR}(t)$ to decrease in amplitude to 0, to thereby form an impulse response series $y'_{RR}(t)$.

Those impulse response series $y'_{LL}(t)$, $y'_{LR}(t)$, $y'_{RL}(t)$ and $y'_{RR}(t)$ are Fourier transformed into transfer functions (frequency characteristics) Y_{LL} , Y_{LR} , Y_{RL} and Y_{RR} .

Then, as in the equations (1) to (5), an inverse matrix Y^{-1} of a 2-row/2-column regular matrix Y of which the elements are the transfer functions Y_{LL} , Y_{LR} , Y_{RL} , Y_{RR} is obtained. The elements of the inverse matrix Y^{-1} are used as correction transfer functions H_{11} , H_{12} , H_{21} and H_{22} of the operator circuits 17 to 20. That is, the transfer functions A_{LL} , A_{LR} , A_{RL} and A_{RR} in the equation (1) are respectively replaced with those transfer functions Y_{LL} , Y_{LR} , Y_{RL} , Y_{RR} calculated anew.

The operator circuits 17 to 20 of the correction circuit 10b are thus designed. Stereophonic audio signals S_L and S_R , which are produced by superimposing the head related transfer functions defined when the listener hears a sound in a sound field on the right- and left-channel signals supplied from a sound source, are supplied to the speakers 13 and 14 in a car cabin 15, through the correction circuit 10b constructed as mentioned above. In this case, the transfer functions B_{LL} , B_{LR} , B_{RL} and B_{RR} are cancelled (corrected) by the correction transfer functions H_{11} , H_{12} , H_{21} and H_{22} of the correction circuit 10b, respectively. Therefore, the listener 16 hears sounds equivalent to those reproduced from the audio signals S_L and S_R on which the head related transfer functions defined when the listener hears in a sound field. Accordingly, the

center sound image is localized in front of the listener 16, and the listener hears the sounds in a sound field expanding symmetrically with respect to the listener in the horizontal direction.

5 Impulse response series $y_{LL}(t)$ to $y_{RR}(t)$ measured in an actual car cabin 15 are amplitude modified by the envelopes of impulse response series $a_{LL}(t)$ to $a_{RR}(t)$ measured in an anechoic room 23 as a model of the car cabin 15, to thereby produce impulse response series $y_{LL}(t)$ to $y_{RR}(t)$, respectively.

10 Then, transfer functions Y_{LL} to Y_{RR} are calculated from those amplitude-modulated impulse response series $y_{LL}(t)$ to $y_{RR}(t)$. Further, the correction transfer functions H_{11} , H_{12} , H_{21} and H_{22} of the operator circuits 17 to 20 are set on the basis of the transfer functions Y_{LL} to Y_{RR} . Therefore, the correction
15 circuit 10b may be constructed by use of simple IIR digital filters.

 The correction transfer functions H_{11} , H_{12} , H_{21} and H_{22} include characteristics, which are featured by the characteristics of the impulse response series $y_{LL}(t)$ to $y_{RR}(t)$,
20 i.e., the sound field characteristics in the actual car cabin 15. Therefore, influence by the transfer functions B_{LL} to B_{RR} in the car cabin 15 shown in Fig. 1 may effectively be corrected.

 In the second embodiment, the impulse response series $y_{LL}(t)$ to $y_{RR}(t)$ measured in the actual car cabin 15 are
25 amplitude modulated by the envelopes of the impulse response

series $a_{LL}(t)$ to $a_{RR}(t)$ measured in the anechoic room 23. It should be understood that many other alterations exist.

In an alteration, parts of the impulse response series $y_{LL}(t)$ to $y_{RR}(t)$ within a period of time taken for the impulse response series $a_{LL}(t)$ to $a_{RR}(t)$ to decrease in amplitude to approximately 0, as of the time period ΔT shown in Figs. 9 and 10 are directly extracted from those impulse response series. functions H_{11} , H_{12} , H_{21} and H_{22} are set on the basis of the transfer functions Y_{LL} to Y_{RR} obtained from the extracted impulse response series $y_{LL}(t)$ to $y_{RR}(t)$. In this alteration, there is no need of amplitude modulating the impulse response series $y_{LL}(t)$ to $y_{RR}(t)$ by the envelopes of the impulse response series $a_{LL}(t)$ to $a_{RR}(t)$ measured in the anechoic room 23.

However, it is desirable to amplitude modulate the impulse response series $y_{LL}(t)$ to $y_{RR}(t)$ by the envelopes of the impulse response series $a_{LL}(t)$ to $a_{RR}(t)$ measured in the anechoic room 23, when considering generation of higher harmonic noise or the like.

It should be understood that the second embodiment described above is presented for ease of understanding the present invention, and hence the invention may be implemented in other many forms. In the description given above, the correction circuit 10b is constructed with four operator circuits 17 to 20, and the adder circuits 21 and 22. If required, those circuits may be substituted by a single digital filter.

It is evident that alteration, modifications, changes and others in design and specification of the audio device as an implementation of the invention fall within the scope of the invention.

5 (Third Embodiment)

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An audio device which is a third embodiment of the present invention will be described with reference to Figs. 11 through 16. In those figures, like or equivalent portions are designated by like reference numerals in Fig. 1. The audio device of the second embodiment is well suitable for use in
10 a room of a house (e.g., a living room) 200.

In Fig. 11, the audio device is made up of an audio device body 100 placed in a room 200 defining a reproduction sound field, right- and left-channel speakers 101L and 101R, and a
15 remote controller 102 operated by a listener 16 for remote control.

The audio device body 100 may be of the unit type in which a CD and/or MD reproduction device for reproducing a recording medium, such as CD or MD, which contains an audio source
20 recorded therein, may selectively be combined into the audio device body or of the integral type in which the unit or units are assembled into a single frame.

The audio device body 100, as shown in a block diagram of Fig. 12, includes a head related transfer function (HRTF)
25 circuit 10a which receives right- and left-channel audio

signals Lin and Rin, which are reproduced by a reproduction device 300 such as a CD or MD reproduction device, a correction circuit 10b and output amplifiers 11 and 12. Further, it includes a control unit 103 with a micro-processor (MPU), a storage unit 104 formed with a re-writable non-volatile semiconductor memory, an optical detecting portion 105 and the like.

In the circuit, the HRTF circuit 10a, correction circuit 10b and output amplifiers 11 and 12 are substantially equal in construction to those in the Fig. 1 circuit. The audio input signals Lin and Rin are correction processed to generate audio signals L and R, and those signals L and R are applied to left and right speakers 101L and 101R, respectively.

The storage unit 104 stores data for setting the correction transfer functions H11, H12, H21 and H22 of the correction circuit 10b as described in the first and second embodiments.

The storage unit 104 stores not only one kind of transfer function data corresponding to one hearing position but also plural kinds of transfer function data {a11, aa12, aa21, aa22}, {bb11, bb12, bb21, bb22}, {cc11, cc12, cc21, cc22}, and {dd11, dd12, dd21, dd22} corresponding to a plurality of hearing positions W, X, Y and Z, as shown in Fig. 14.

Four transfer data items corresponding to four hearing positions W, X, Y, Z are exemplarily shown in Fig. 14. It is

clear that a desired number of hearing positions and different kinds of transfer function data corresponding to them may be used.

5 The optical detecting portion 105 includes an opto-electric transducing elements which receives an optical signal from the remote controller 102 and converts it into a corresponding electric signal, and supplies the electric signal to the control unit 103.

10 The control unit 103 detects code data indicative of a hearing position, which is contained in an electric signal derived from the optical detecting portion 105, makes an access to the storage unit 104 to read out the transfer function data in accordance with the detected code data, and transfers the readout data to the correction circuit 10b.

15 When the listener operates a given operation button switch provided on the remote controller 102, the remote controller 102 emits an optical signal containing code data indicative of a hearing position defined by the operation button switch. The control unit 103 makes an access to the
20 storage unit 104 according to the code data and reads out the transfer data corresponding to the code data, and causes the transfer of it from the storage unit 104 to the correction circuit 10b. As a result, the transfer functions in the correction circuit 10b are updated to or replaced with the
25 transfer functions instructed by the listener.

Fig. 13 is a plan view showing an external appearance of the remote controller 102. In the figure, the remote controller 102 includes a plurality of function keys F1 to F3, and ten keys 1-6 specified with numerals. Those keys F1 to F3 and 106 are operation button switches. A light emission portion 107 with an infrared-ray light emitting element which emits an optical signal is provided at the top of the remote controller 102.

A decoder circuit which detects any of the function keys F1 to F3 and the ten keys 106, which is depressed, and generates code data of a hearing position corresponding to the detected key is provided in the frame of the remote controller 102. Further, a modulator circuit which modulates code data indicative of the hearing position output from the decoder circuit, and supplies the resultant to the light emission portion 107. Additionally, a drive circuit which power amplifies the output signal of the modulator circuit and applies the resultant to the infrared-ray light emitting element, and causes the light emission portion 107 to emit light containing the code data, is further provided.

The decoder circuit is designed so as to generate code data of the hearing positions, W, X, Y and Z corresponding to the ten keys 106, as shown in Fig. 15.

When the function key F1 is depressed and then any of the keys (1), (2) and (3) of those ten keys 106 is depressed,

it generates code data indicative of a hearing position W. When any of the keys (4), (5) and (6) of those ten keys 106 is depressed, then it generates code data indicative of a hearing position X. When any of the keys (7), (8) and (9) of those ten keys 106 is depressed, then it generates code data indicative of a hearing position Y. When a "*" key is depressed, then it generates code data indicative of a hearing position Z.

The correspondence between those ten keys 106 and the hearing positions is presented by way of example. If required, another correspondence may be employed, as a matter of course.

The function key F1 is provided for updating the transfer functions in the correction circuit 10b, viz., for mode selection. The function key F2 is provided for designating the CD reproduction device of the reproduction device 300 and controlling its operation. When the listener depresses the function key F2 and depresses the key (1) of the ten keys 106, a musical piece recorded in the first track of the CD as a recording medium is reproduced.

A method of generating transfer function data stored in the storage unit 104 shown in Fig. 14 will be described.

Right and left speakers are disposed in an anechoic room which is a model of the room 200 as a reproduction sound field. A dummy listener is located at a hearing position in the anechoic room, which corresponds to the hearing position W in

the room 200. Pulse sounds emitted from the right and left speakers are gathered by microphones, whereby the impulse response series described in the first and second embodiments are obtained. The transfer function data {aa11, aa12, aa21, aa22} corresponding to the hearing position W is generated in accordance with the impulse response series. The transfer function data {bb11, bb12, bb21, bb22} of the transfer functions defined when a dummy listener is located at a hearing position corresponding to the hearing position X in the room 200 is generated in like manner. The transfer function data {bb11, bb12, bb21, bb22} of the transfer functions defined when a dummy listener is located at a hearing position corresponding to the hearing position Y in the room 200 is generated in like manner. Further, the transfer function data {dd11, dd12, dd21, dd22} of the transfer functions defined when a dummy listener is located at a hearing position corresponding to the hearing position Z in the room 200 is generated in like manner.

Those data pieces of the thus generated transfer functions are made to correspond to the ten keys 106 and the function key F1 on the remote controller 102, respectively. Those transfer function data pieces may be stored in the storage unit 104 in a factory or distributed to users in the form of a semiconductor memory storing those transfer function data pieces.

An operation of the audio device when the listener

operates the remote controller 102 in the room 200 will be described.

Let us consider a case where the listener 16 moves to the hearing position Y in the room 200, and depresses the function key F1 on the remote controller 102 and the key (7) of the ten keys 106. In this case, the light emission portion 107 emits light containing the code data of the hearing position Y. The optical detecting portion 105 receives the light, and the storage unit 104 causes the transfer of the transfer function data {cc11, cc12, cc21, cc22} corresponding to the hearing position Y from the storage unit 104 to the correction circuit 10b. Then, the transfer function data in the correction circuit 10b is updated to the transfer function data {cc11, cc12, cc21, cc22}.

When the transfer functions are thus updated in the correction circuit 10b, correction is made of influence by the transfer functions BLL and BLR in a sound field from the left channel speaker 101L to the right and left ears 16R and 16L of the listener 16 who is placed at the hearing position Y, and the transfer functions BRL and BRR in a sound field from the right channel speaker 101R to the right and left ears 16R and 16L of the listener 16 who is placed at the hearing position Y (model diagram of Fig. 11), to thereby localize a sound image in front of the listener 16. As a result, a stereophonic, natural sound is reproduced.

When the listener 16 moves to the hearing position X in the room 200, and depresses the key (4) on the remote controller 102, the transfer functions in the correction circuit 10b are updated to the {bb11, bb12, bb21, bb22}, the sound image is localized in front of the listener 16 who is placed at the hearing position X, and a natural sound is reproduced. When the listener 16 moves to the hearing position W, and depresses the key (1) on the remote controller 102, the sound image is localized in front of the listener 16 who is placed at the hearing position W, and a natural sound is reproduced. When the listener 16 moves to the hearing position Z, and depresses the key "*" on the remote controller 102, the sound image is localized in front of the listener 16 who is placed at the hearing position Z, and a natural sound is reproduced.

As described above, in the embodiment, the transfer function data corresponding to the predetermined hearing positions in the room 200 as a reproduction sound field space is stored, and the transfer functions are updated every time the listener changes his hearing position. Therefore, the listener 16 hears a sound in a sound field expanding asymmetrically with respect to the listener in the horizontal direction.

In the third embodiment described above, the listener 16 operates the ten keys 106 on the remote controller 102 to give an instruction of a hearing position to the audio device

body 100. Any other suitable technical means may be employed for the same purpose. An example of it is shown in Fig. 16, as a modification of the audio device.

In Fig. 16, a couple of opto-electric transducing element
5 105a and 105b are provided while being spaced from each other a predetermined distance. When the listener 16 operates the remote controller 102 at a given position, the light emission portion 107 emits infrared rays. The infrared rays emitted are received by the opto-electric transducing elements 105a
10 and 105b. The control unit 103 carries out a geometrical operation process about the relative positions of the opto-electric transducing elements 105a and 105b by use of the light receiving results from the opto-electric transducing elements 105a and 105b, and judges the present position
15 (hearing position) of the listener 16. Then, it reads out the transfer function data corresponding to the judged hearing position from the storage unit 104 shown in Fig. 4, and updates the transfer functions in the correction circuit 10b.

In the audio device thus constructed, there is no need
20 of operating the ten keys 106 on the remote controller 102. Accordingly, if the function key F1 on the remote controller 102 is assigned to the infrared ray emission, the listener 16 may inform the audio device body 100 of the hearing position by a simple operation of merely depressing the function key
25 F1. This leads to improvement of operation facility of the

audio device.

While the opto-electric transducing elements 105a and 105b for receiving light from the remote controller 102 are provided on the audio device body 100, those may be attached
5 to the ends of the right and left speakers 101R and 101L.

In the third embodiment, the audio device installed in the room 200 of a house or the like is discussed. It is evident that the audio device may be applied to the car-carried audio device.

10 As described above, in the audio device of the invention, the audio signals of both channels are corrected in advance by a correction circuit (operator circuits) having transfer functions featured by the sound field characteristics in a space between the speakers of both channels and a listener.
15 And the corrected audio signals are supplied to the speakers. Therefore, the listener may hear a sound equivalent to a sound reproduced from the audio signals on which the head related transfer functions defined when the listener hears a sound in a sound field are superimposed. The center sound image is
20 localized in front of the listener, and he hears a sound in a sound field expanding symmetrically with respect to the listener in the horizontal direction.

When the listener changes his hearing position, position detecting means sets the transfer functions based on the
25 hearing position changed. Therefore, the listener hears a

sound in a sound field expanding symmetrically with respect to the listener in the horizontal direction is provided to the listener, while being unconscious of the hearing position.

WHAT IS CLAIMED IS:

1. An audio device comprising:

a correction circuit having given transfer functions, which audio device supplies, through said correction circuit, right- and left-channel input audio signals on which head related transfer functions are superimposed, to right- and left-channel speakers located in front of a hearing position of a listener in a reproduction sound field space, wherein

correction transfer functions obtained by an inverse matrix of a matrix of which the elements are the following first to fourth transfer functions are implanted in said correction circuit;

a first transfer function featured by a sound field characteristic of a space ranging from a left-channel speaker to the left ear of the listener when said left-channel speaker is disposed in an anechoic room as a model of a component layout in said reproduction sound field space,

a second transfer function featured by a sound field characteristic of a space ranging from a left-channel speaker to the right ear of the listener when said left-channel speaker is disposed in an anechoic room as a model of a component layout in said reproduction sound field space,

a third transfer function featured by a sound field characteristic of a space ranging from a right-channel speaker to the left ear of the listener when said right-channel speaker

is disposed in an anechoic room as a model of a component layout in said reproduction sound field space, and

5 a fourth transfer function featured by a sound field characteristic of a space ranging from a right-channel speaker to the right ear of the listener when said right-channel speaker is disposed in an anechoic room as a model of a component layout in said reproduction sound field space.

2. An audio device comprising:

10 a correction circuit having given transfer functions, which audio device supplies, through said correction circuit, right- and left-channel input audio signals on which head related transfer functions are superimposed, to right- and left-channel speakers located in front of a hearing position
15 of a listener in a reproduction sound field space, wherein

said correction circuit includes first to fourth operator circuits, and first and second adder circuits, and correction transfer functions obtained by an inverse matrix of a two-row and two-column matrix of which the elements are
20 the following first to fourth transfer functions are implanted in said first to third operator circuits;

said first transfer function is obtained from a third impulse response series, which is extracted from a second impulse response series of a first impulse response series,
25 which said second impulse response series is featured by a sound

field characteristic from a left-channel speaker to the listener when said left-channel speaker is disposed in an anechoic room as a model of a component layout in said reproduction sound field space, said first impulse response series being featured by a sound field characteristic of a space ranging from a left-channel speaker to the left ear of the listener when said left-channel speaker is disposed in said reproduction sound field space,

said second transfer function is obtained from a sixth impulse response series, which is extracted from a fifth impulse response series of a fourth impulse response series, which said fifth impulse response series is featured by a sound field characteristic of a space ranging from a left-channel speaker to the right ear of the listener when said left-channel speaker is disposed in an anechoic room as a model of a component layout in said reproduction sound field space, said fourth impulse response series being featured by a sound field characteristic of a space ranging from a left-channel speaker to the right ear of the listener when said left-channel speaker is disposed in said reproduction sound field space,

said third transfer function is obtained from a ninth impulse response series, which is extracted from an eighth impulse response series of a seventh impulse response series, which said eighth impulse response series is featured by a sound field characteristic of a space ranging from a right-channel

speaker to the left ear of the listener when said left-channel speaker is disposed in an anechoic room as a model of a component layout in said reproduction sound field space, said seventh response series being featured by a sound field characteristic of a space ranging from a right-channel speaker to the left ear of the listener when said right-channel speaker is disposed in said reproduction sound field space, and

said fourth transfer function is obtained from a 12th impulse response series, which is extracted from an 11th impulse response series of a 10th impulse response series, which said 11th impulse response series is featured by a sound field characteristic of a space ranging from a right-channel speaker to the right ear of the listener when said right-channel speaker is disposed in an anechoic room as a model of a component layout in said reproduction sound field space, said 10th response series being featured by a sound field characteristic of a space ranging from a right-channel speaker to the right ear of the listener when said right-channel speaker is disposed in said reproduction sound field space, and

said first adder circuit adds together output signals of said first and third operator circuits when said left-channel input audio signal is input to said first operator circuit, and said right-channel input audio signal is input to said third operator circuit, and

said second adder circuit adds together output signals

of said second and fourth operator circuits when said left-channel input audio signal is input to said second operator circuit, and said right-channel input audio signal is input to said fourth operator circuit.

5

3. The audio device according to claim 2, wherein

said third impulse response series is extracted from a part of said first impulse response series within a period of time taken for a damping amplitude of said second impulse response series decreases to approximately 0 (zero),

said sixth impulse response series is extracted from a part of said fourth impulse response series within a period of time taken for a damping amplitude of said fifth impulse response series decreases to approximately 0 (zero),

said ninth impulse response series is extracted from a part of said seventh impulse response series within a period of time taken for a damping amplitude of said eighth impulse response series decreases to approximately 0 (zero), and

said 12th impulse response series is extracted from a part of said 10th impulse response series within a period of time taken for a damping amplitude of said 11th impulse response series decreases to approximately 0 (zero).

4. The audio device according to claim 2, wherein

said third impulse response series is extracted by a

window function in which said first impulse response series is featured by an envelop of said second impulse response series,

5 said sixth impulse response series is extracted by a window function in which said fourth impulse response series is featured by an envelop of said fifth impulse response series,

10 said ninth impulse response series is extracted by a window function in which said seventh impulse response series is featured by an envelop of said eighth impulse response series, and

 said 12th impulse response series is extracted by a window function in which said 10th impulse response series is featured by an envelop of said 11th impulse response series.

15 5. An audio device comprising:

 a correction circuit having given transfer functions, which audio device supplies, through said correction circuit, right- and left-channel input audio signals on which head related transfer functions are superimposed, to right- and
20 left-channel speakers located in front of a hearing position of a listener in a reproduction sound field space,

 storing means for storing correction transfer functions corresponding to a plurality of spatial regions; and

25 position detecting means for specifying a hearing position of the listener in said a plurality of spatial regions,

wherein

said correction transfer functions stored in said storing means, the said correction transfer functions specified according to a hearing position of the listener
5 detected by said position detecting means are implanted in said correction circuit,

correction transfer functions, which are obtained in accordance with a plurality of spatial regions within a predetermined reproduction sound field space by an inverse
10 matrix of a matrix of which the elements are the following first to fourth transfer functions are implanted in said correction circuit being determined in advance, and wherein

said first transfer function featured by a sound field characteristic of a space ranging from a left-channel speaker
15 to the left ear of the listener when said left-channel speaker is disposed in an anechoic room as a model of a component layout in said reproduction sound field space,

said second transfer function featured by a sound field characteristic of a space ranging from a left-channel speaker
20 to the right ear of the listener when said left-channel speaker is disposed in an anechoic room as a model of a component layout in said reproduction sound field space,

said third transfer function featured by a sound field characteristic of a space ranging from a right-channel speaker
25 to the left ear of the listener when said right-channel speaker

is disposed in an anechoic room as a model of a component layout
in said reproduction sound field space, and

said fourth transfer function featured by a sound field
characteristic of a space ranging from a right-channel speaker
5 to the right ear of the listener when said right-channel speaker
is disposed in an anechoic room as a model of a component layout
in said reproduction sound field space.

ABSTRACT OF THE DISCLOSURE

A dummy listener and right and left speakers 13 and 14 are disposed in an anechoic room as a model of the layout of those a car cabin 15 or the like. Transfer functions ALL, ALR, ARL and ARR in a space ranging from the speakers 13 and 14 to the right and left ears of a listener 16 in a car cabin 15 or the like are calculated from impulse response series aLL(t) to aRR(t) obtained when pulse sounds are respectively emitted from the speakers 13 and 14. A correction circuit 10b contains correction transfer functions H11, H12, H21 and H22, which are obtained by an inverse matrix of a 2-row and 2-column regular matrix of which the elements are the transfer functions ALL, ALR, ARL and ARR. Audio signals SL and SR on which head related transfer functions are superimposed are applied to the correction circuit 10b, and the output signals of the correction circuit 10b are supplied to the speakers 13 and 14.

[Fig. 6]

- (a) impulse response of H11
- (b) impulse response of H12
- (c) impulse response of H21
- (d) impulse response of H22

[Fig. 7]

- (a) frequency characteristic of H11
- (b) frequency characteristic of H12
- (c) frequency characteristic of H21
- (d) frequency characteristic of H22

[Fig. 11]

100: audio device body

[Fig. 12]

300: reproduction device

10a: HRTF circuit

10b: correction circuit

104: storage unit

103: control unit (CPU)

105: optical detecting portion

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[Fig. 14]

A: code of hearing position

B: transfer function data

[Fig. 15]

A: code of hearing position

B: ten keys

[Fig. 16]

300: reproduction device

10a: HRTF circuit

10b: correction circuit

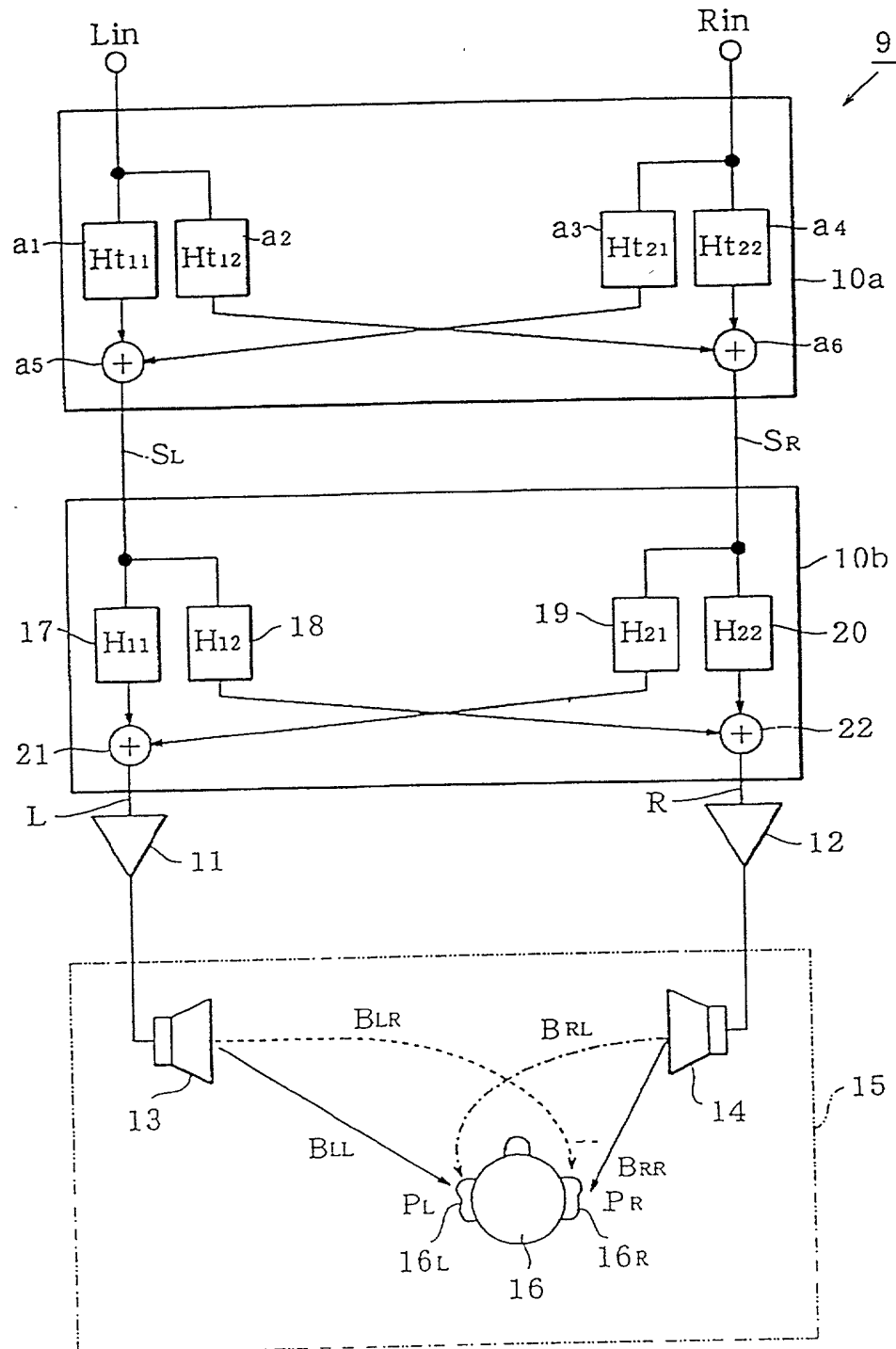
104: storage unit

103: control unit (CPU)

105: optical detecting portion

{書類名} 図面

{図1} Fig. 1



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〔図4〕

Fig. 4A

(a)

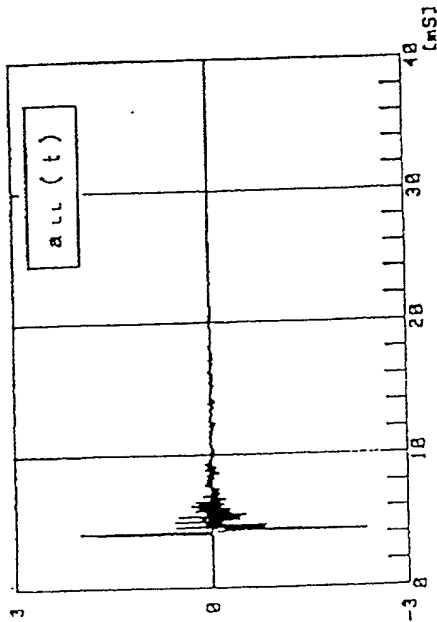


Fig. 4B

(b)

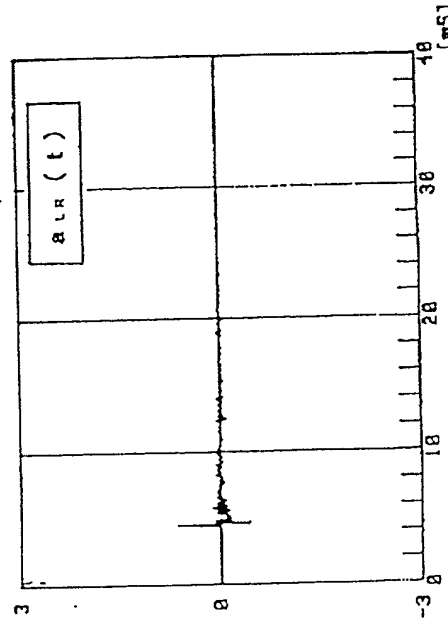


Fig. 4C

(c)

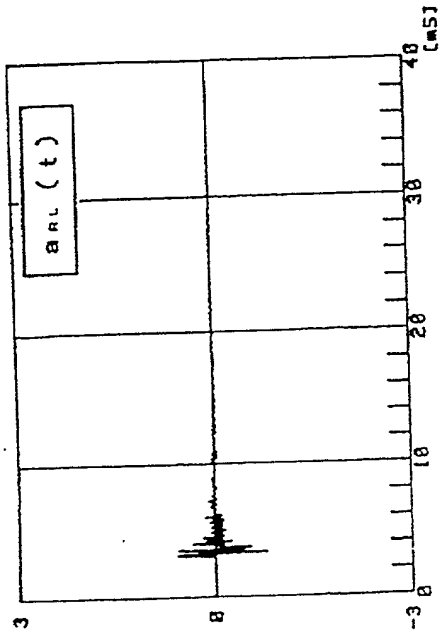
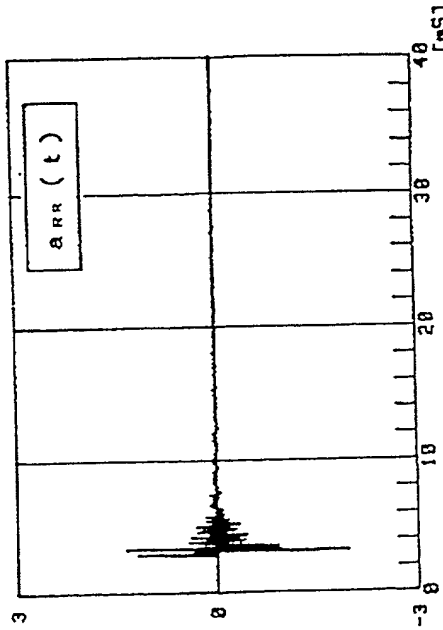


Fig. 4D

(d)



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(図5)

Fig. 5c
(c)

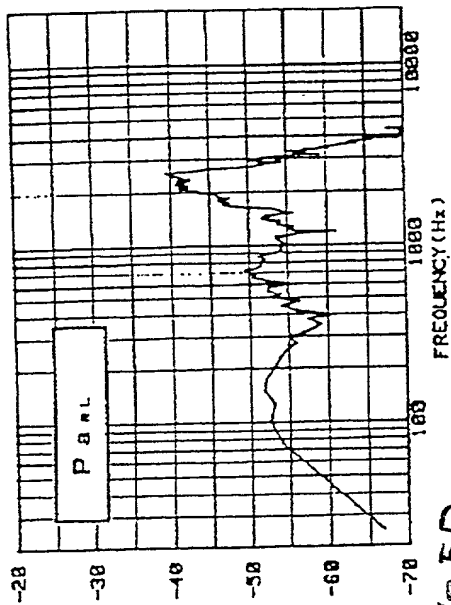


Fig. 5D
(d)

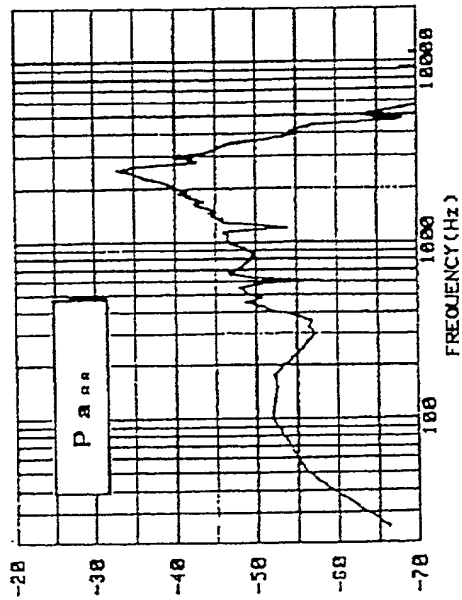


Fig. 5A
(a)

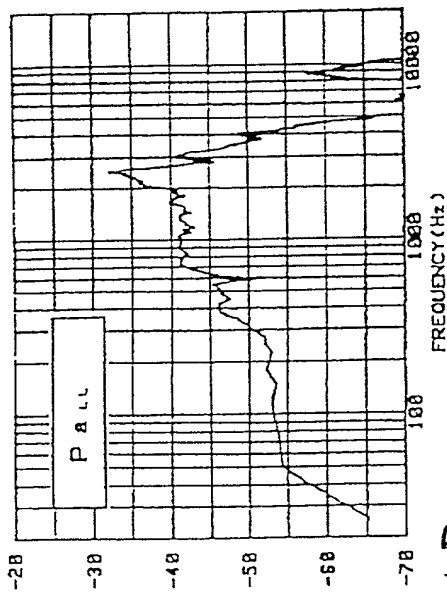
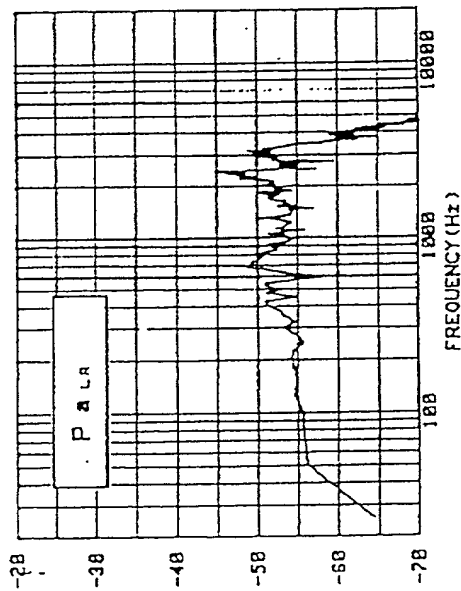


Fig. 5B
(b)



〔図6〕

Fig. 6A

(a)

(a)

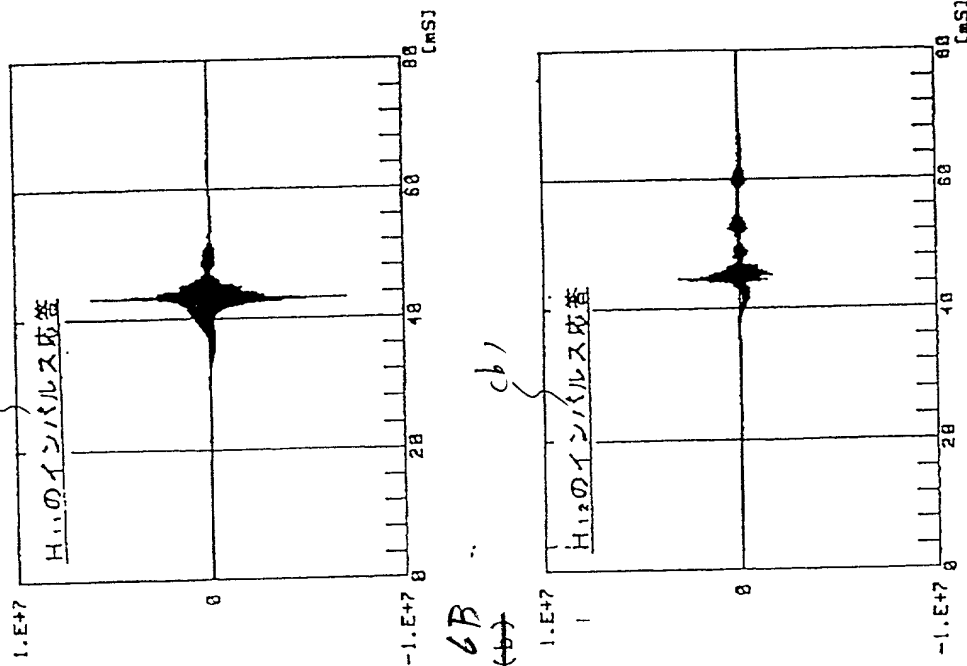


Fig. 6c

(c)

(c)

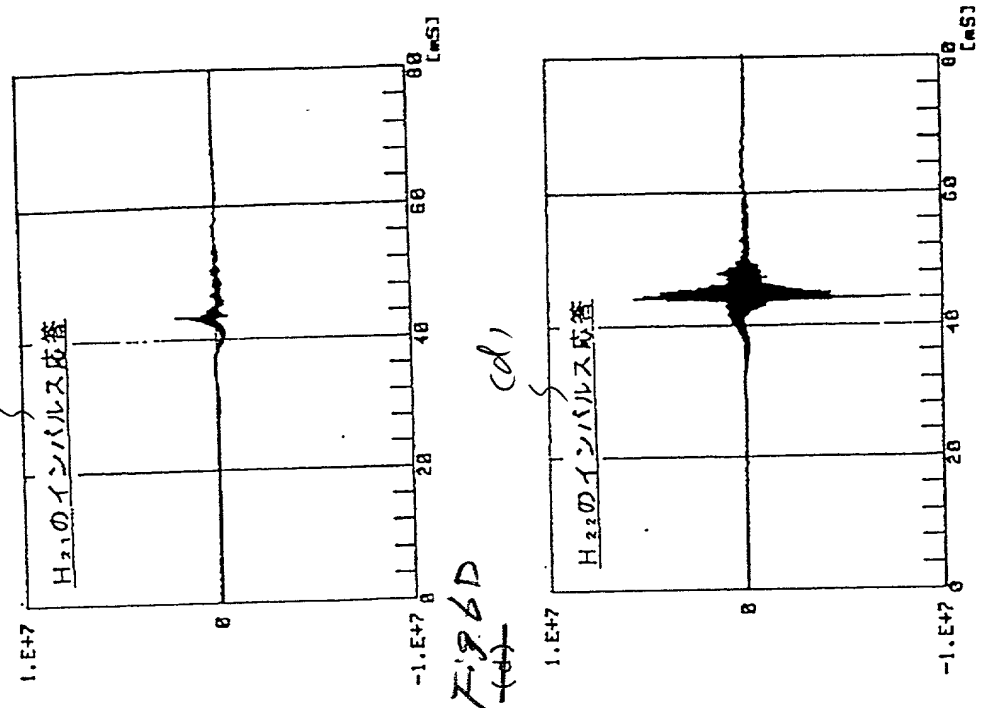


Fig. 6D

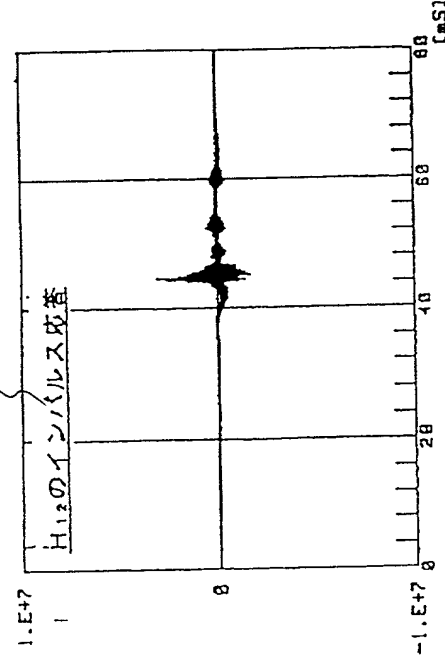
(d)

(d)

Fig. 6B

(b)

(b)



(図7)

Fig. 7A

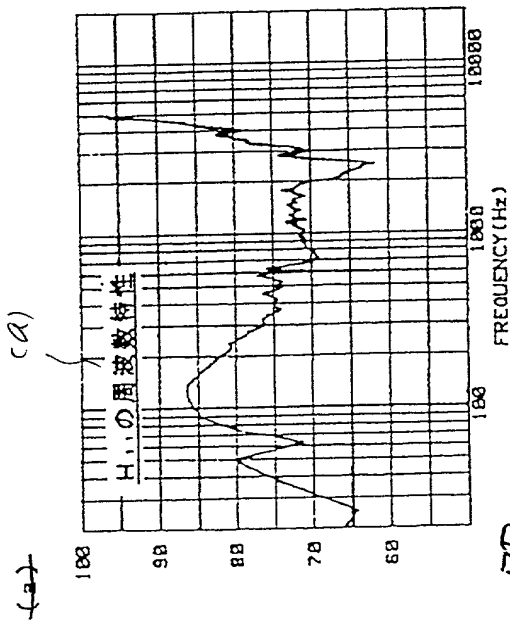


Fig. 7C

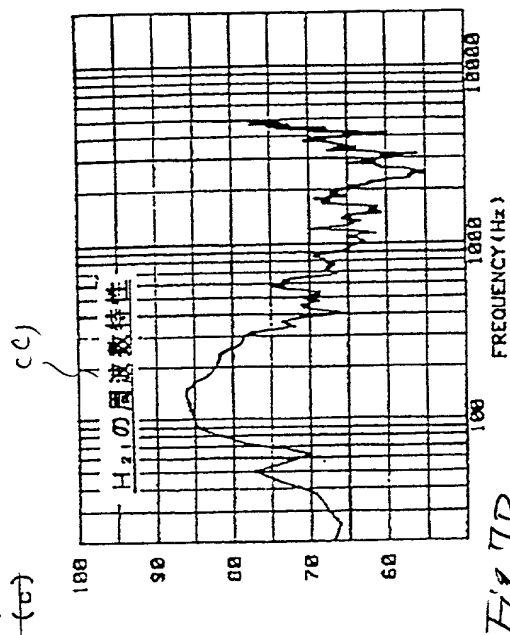


Fig. 7B

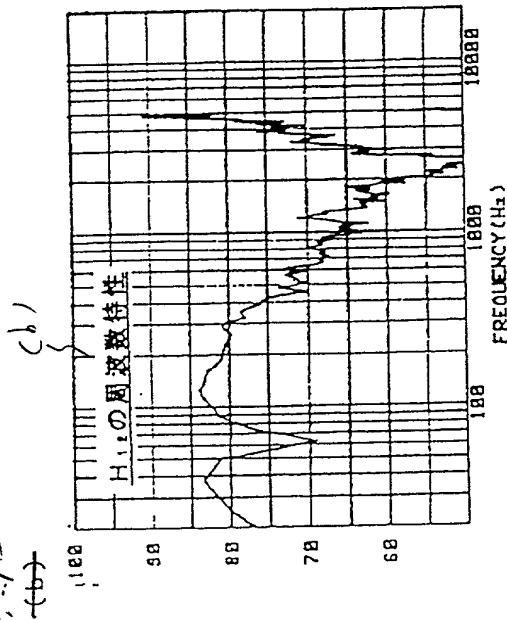
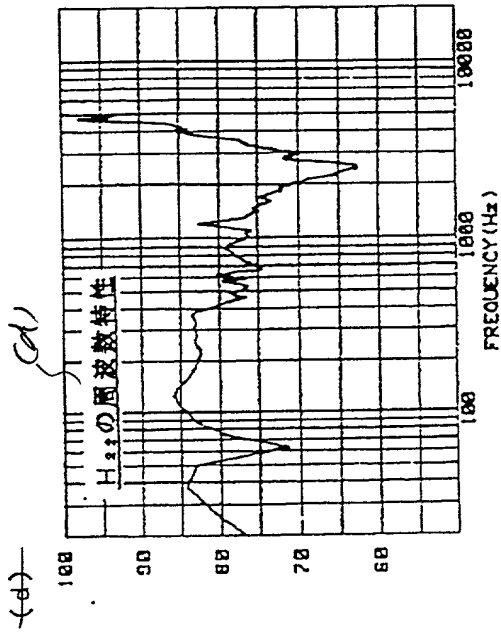


Fig. 7D



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(図8)

Fig. 8A

(a)

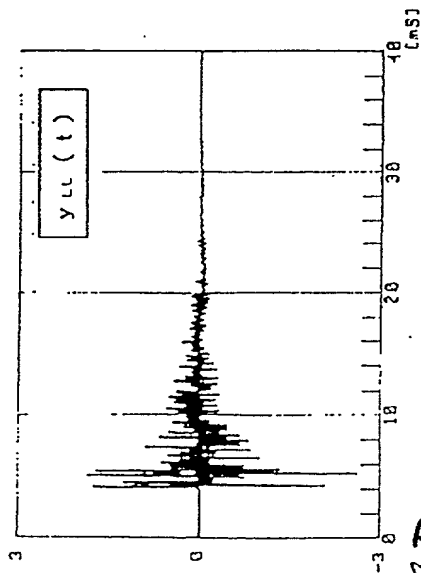


Fig. 8B

(b)

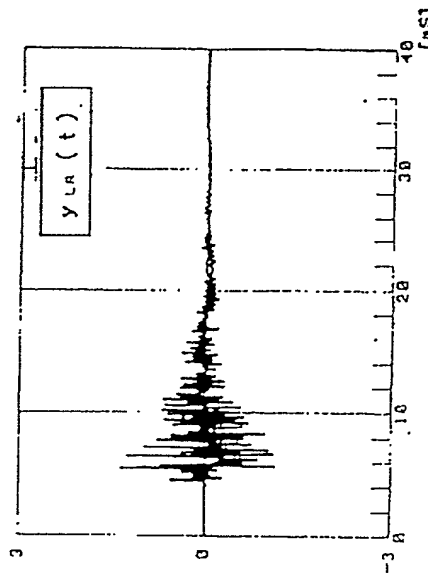


Fig. 8C

(c)

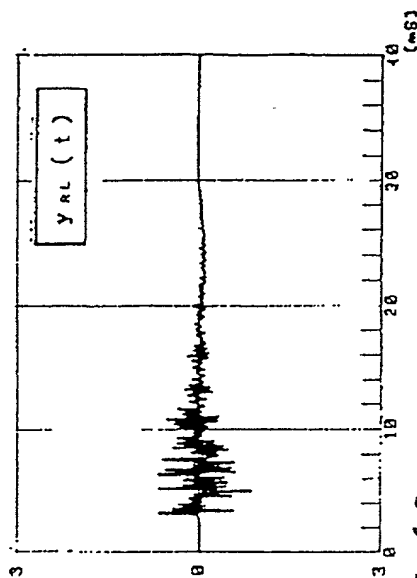
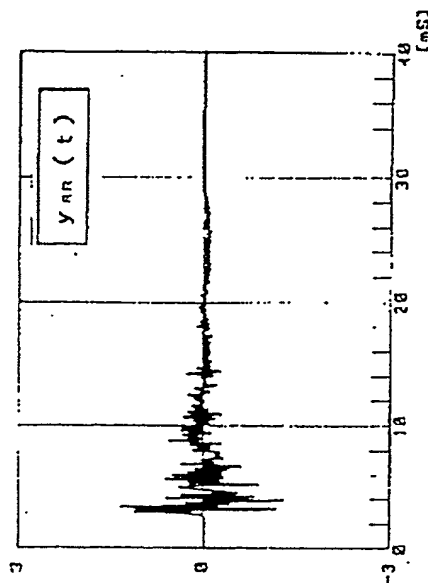


Fig. 8D

(d)



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Fig. 9A

test

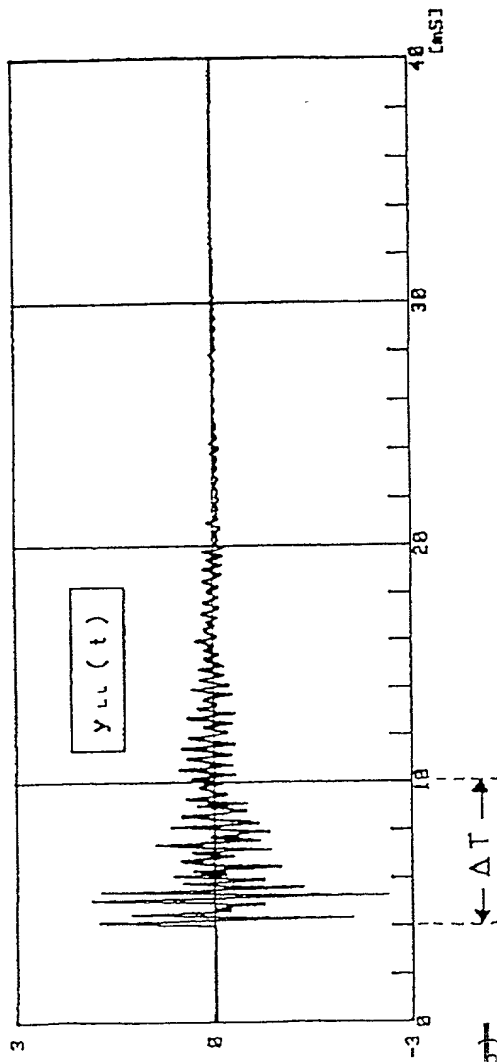
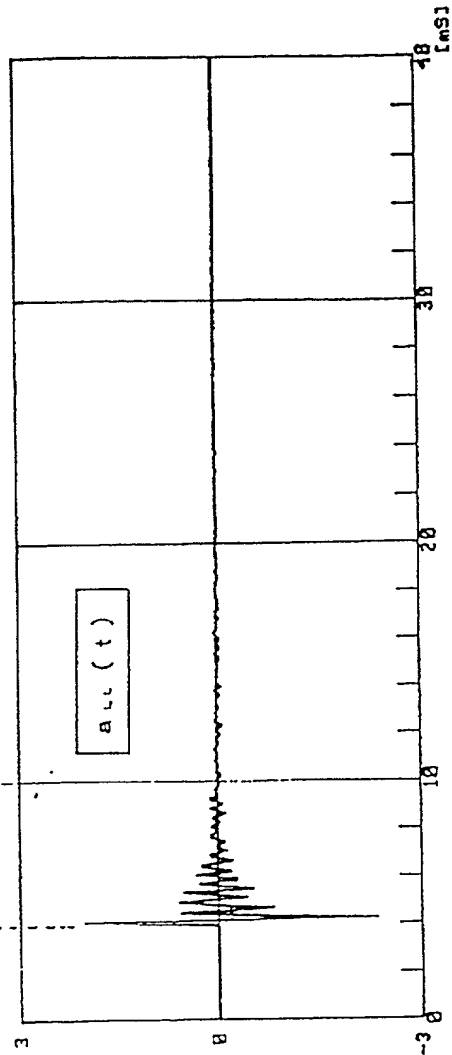


Fig. 9B

test



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Fig. 10A

---(t)---

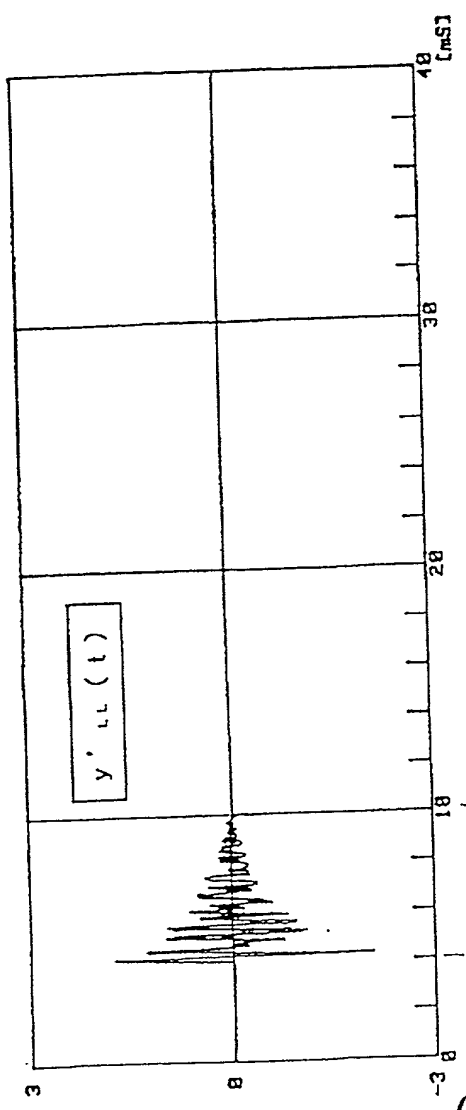
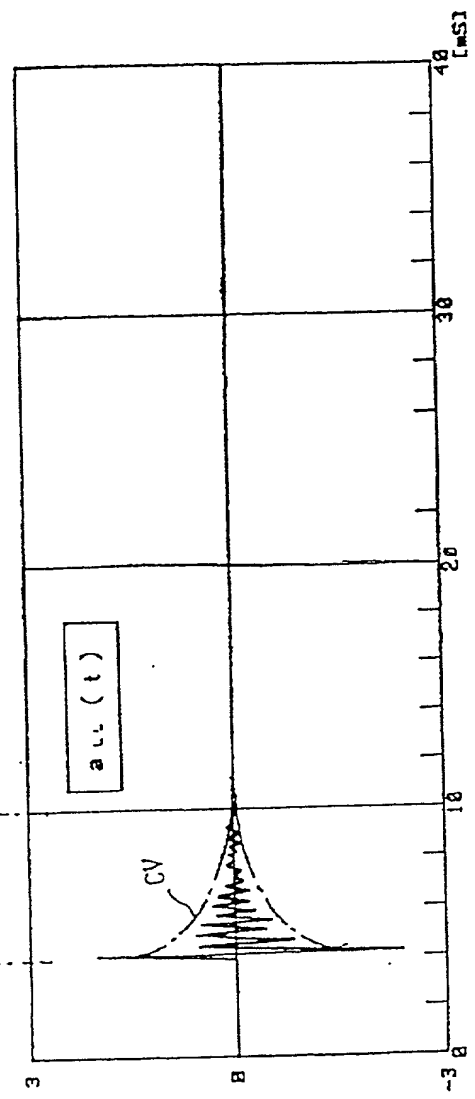
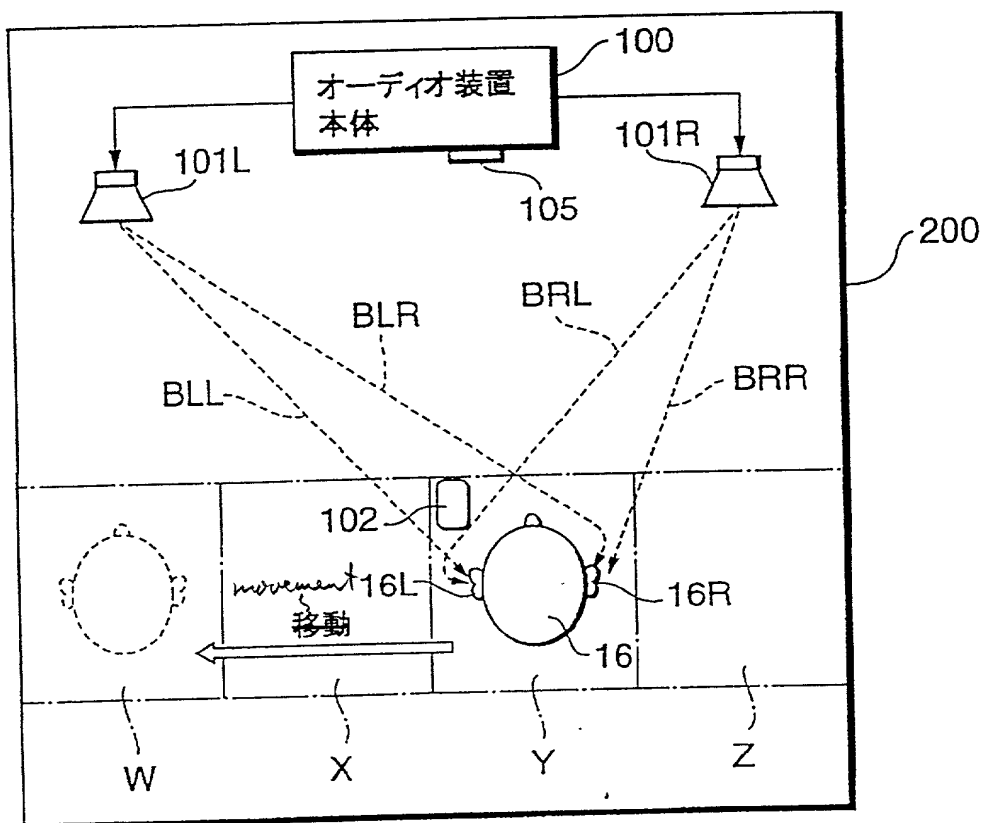


Fig. 10B

---(t)---

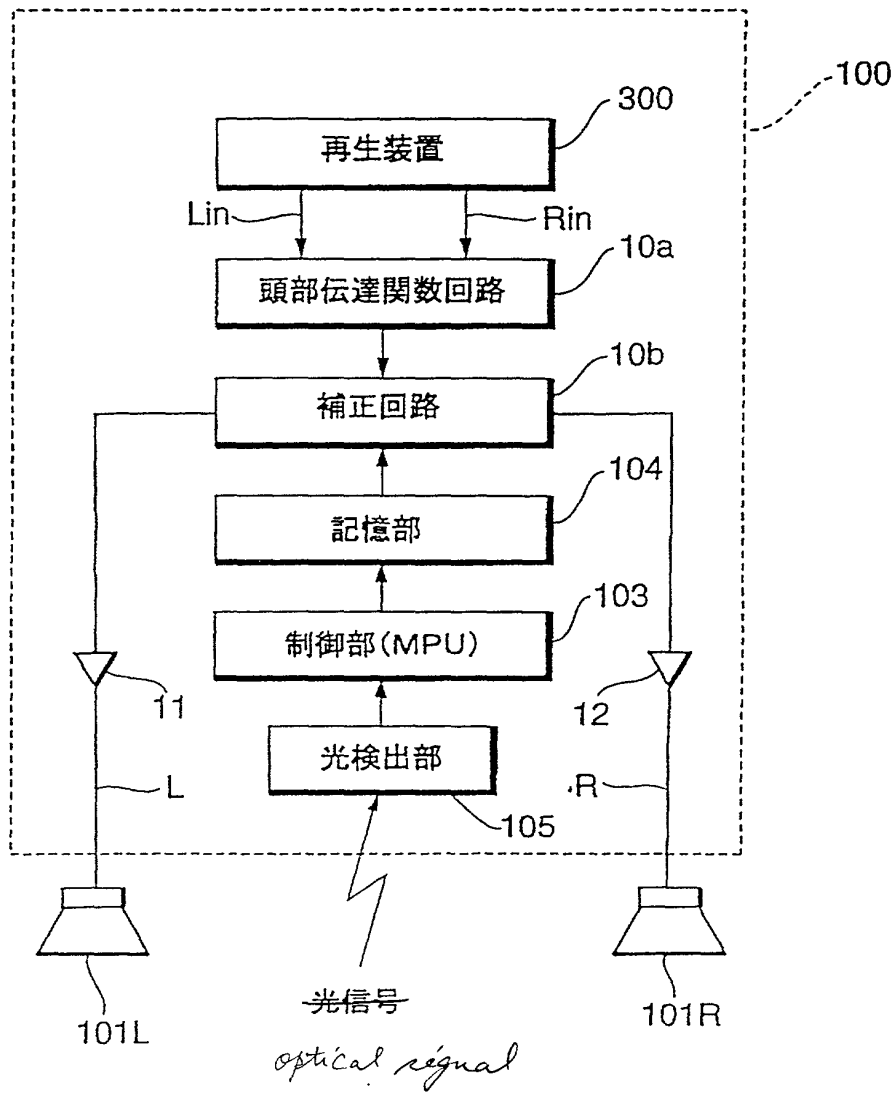


(図11) Fig. 11



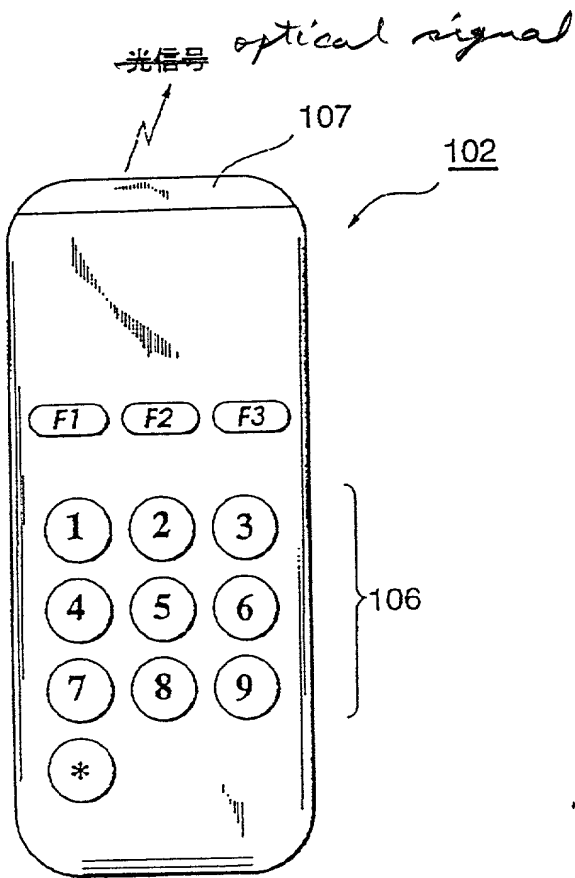
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[図12] Fig. 12



[図13]

Fig. 13



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~~(図14)~~ Fig 14

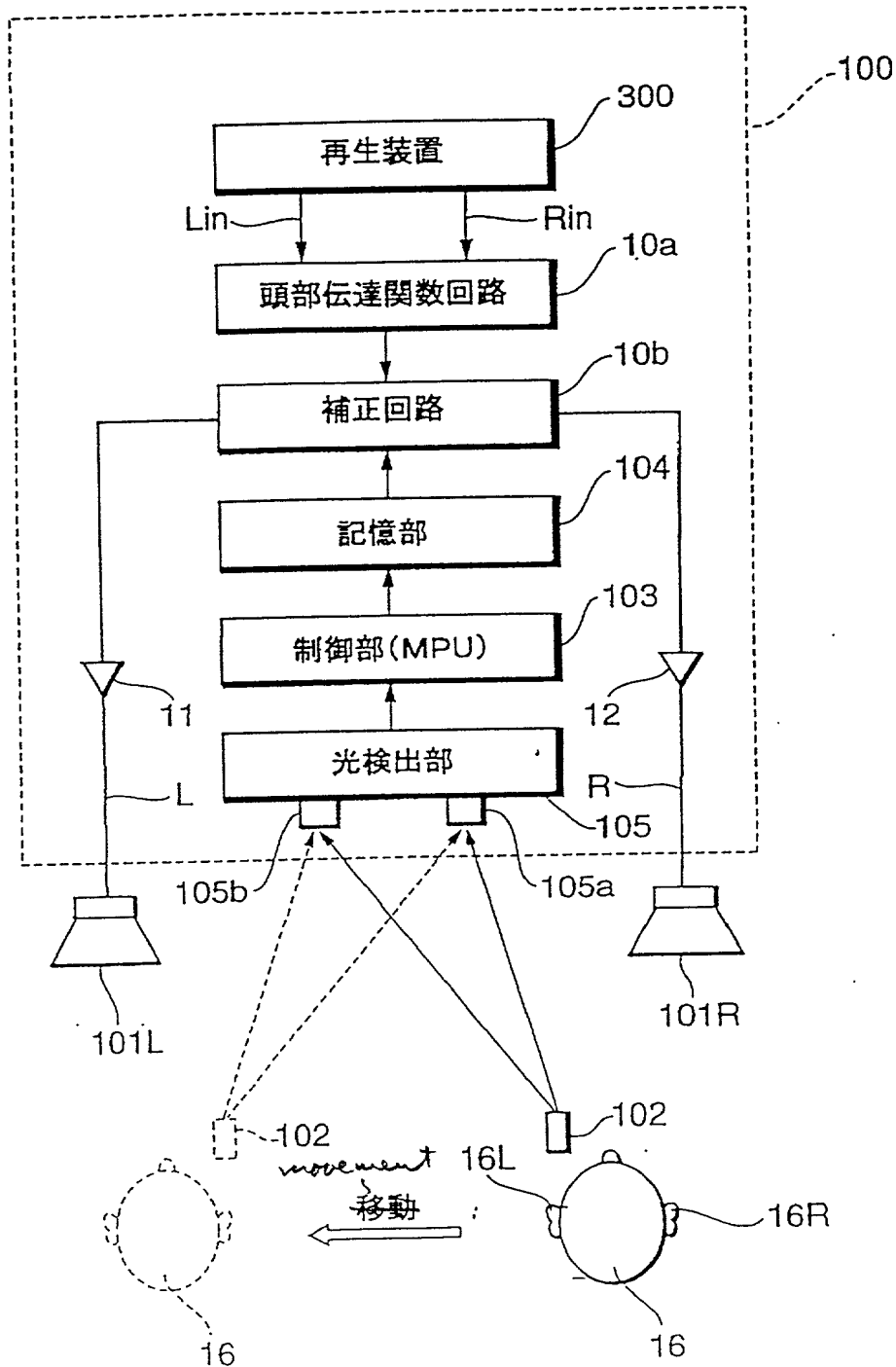
A		伝達関数のデータ			
	聴取位置のコード	H11	H12	H21	H22
	W	aa11	aa12	aa21	aa22
	X	bb11	bb12	bb21	bb22
	Y	cc11	cc12	cc21	cc22
	Z	dd11	dd12	dd21	dd22

~~(図15)~~ Fig. 15

A	聴取位置のコード	テンキー		
	W	①	②	③
	X	④	⑤	⑥
	Y	⑦	⑧	⑨
	Z	*	-	

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【図16】 Fig. 16



(図17)

Fig. 17A (a)

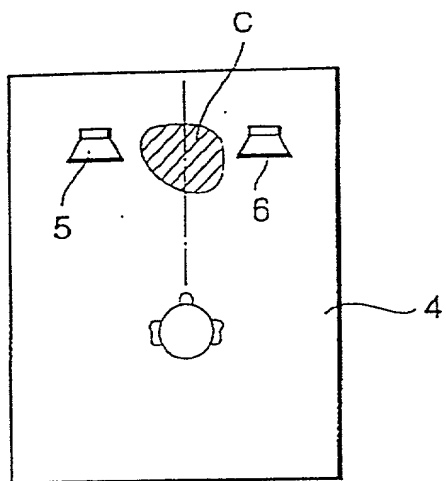


Fig. 17B (b)

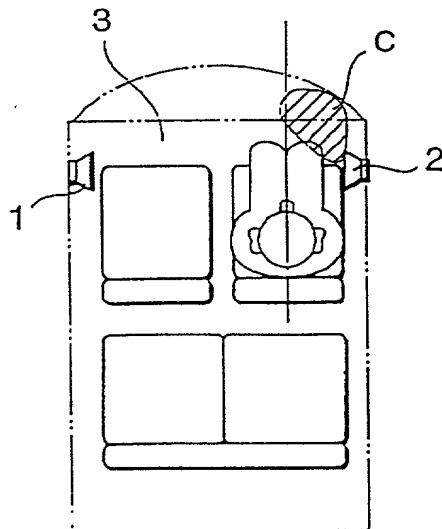


Fig. 17C (c)

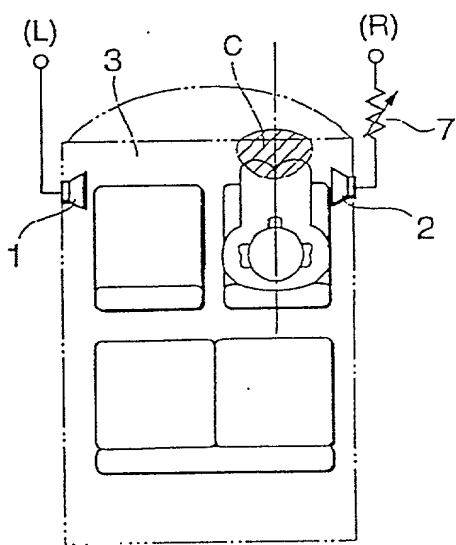
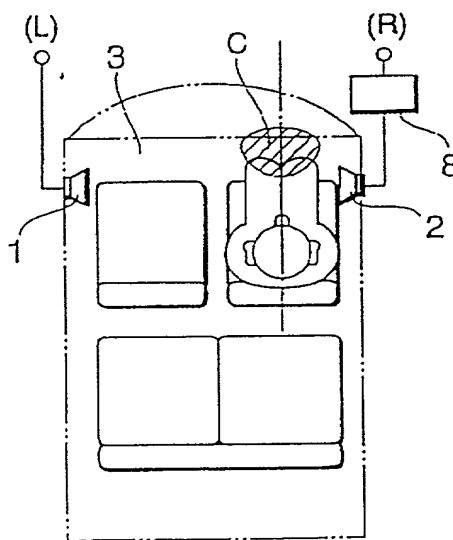


Fig. 17D (d)



DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

AUDIO DEVICE

the specification of which is attached hereto unless the following box is checked:

☐ was filed on _____ as United States Application Number or PCT International Application Number _____ and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information of which is material to the patentability as defined in 37 CFR § 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. § 119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT International application which designated at least one country other than United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

Priority Not Claimed

P. Hei. 11-165651

Japan

11/June/1999

☐

(Number)

(Country)

(Day/Month/Year Filed)

P. 2000-119787

Japan

20/April/2000

☐

(Number)

(Country)

(Day/Month/Year Filed)

☐

(Number)

(Country)

(Day/Month/Year Filed)

I hereby claim the benefits under 35 U.S.C. § 119(e) of any United States provisional application(s) listed below.

(Application Number)

(Filing Date)

I hereby claim the benefits under 35 U.S.C. § 120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

(Application Number)

(Filing Date)

(Status - patented, pending, abandoned)

(Application Number)

(Filing Date)

(Status - patented, pending, abandoned)

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Citizenship